NOISE AND DUST SURVEY IN MINES

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
in
Mining Engineering

By

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Department of Mining Engineering
National Institute of Technology
Rourkela-769008
2012

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CERTIFICATE

This is to certify that the thesis entitled "**Noise and Dust Survey in Mines**" submitted by **Sri Prakash Prabhakar**, Roll No**. 108MN038** in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any Degree of Diploma**.**

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Date: 14/05/2012 **Prakash Prabhakar**

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ABSTRACT

Opencast and underground mining operations produce large quantities of dust as well noise due to increased mechanisation to augment production and enhance productivity to meet the demands of consumer industry. Exposure of miners to high concentrations of dust and noise may cause occupational health hazards like pneumoconiosis and noise induced hearing loss and other allied health risk. Health risk to miners from dust depends on dust size, concentration and duration of exposure whereas noise induced hearing loss depends on sound pressure level, frequency and exposure level of workers. Exposure of workers to dust concentrations and sound pressure levels beyond threshold limit values as prescribed limits by statutory enactments and guidelines may adversely affect the health of mine workers. To assess the status of dust concentrations and noise levels generated by various machines and exposure levels of workers, conduct of systematic dust and noise survey in mines is essential. It will help in assessing the situation vis-a-vis dust and noise standards so that effective dust and noise control strategies can be adopted to minimize their menace.

Keeping this in view, this project work was undertaken to carry out dust and noise survey in an iron ore mine of SAIL. From dust and noise survey carried out in Bolani iron ore mines, it was observed that:

- The dust level at the mine site office was minimum (0.14 mg/m^3) whereas the maximum dust level was found at the crusher plant area (3.1 mg/m^3). The dust concentration at lump loading station, fine loading station, mine face and mine site office was less than safe working limit(3 mg/m^3) whereas at the washing plant and crusher plant area were found more than the safe working limit.
- The noise level at the secondary cone crusher was maximum (102.2 dBA) whereas at the control room minimum (76.2 dBA). The noise level at dumper, drill machine, drum scrubber, double deck screen and dewatering screen was more than 90 dBA which is maximum permissible limit for 8 hrs working period. Whereas the noise level at loading station, hopper, shovel, and control room was below the permissible limit 90 dBA. Hence we can say that the worker of the Iron Ore Mine, Bolani are working under high noise level more than the acceptable level.

- From the modelling of the Noise rating from Mamdani Fuzzy System, the noise rating for different machineries were determined and compared with the field data for the Noise Rating and it was found that the results were satisfactory.

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INTRODUCTION

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INTRODUCTION

Opencast and underground mining operations produce large quantities of dust as well noise due to increased mechanisation to augment production and enhance productivity to meet the demands of consumer industry. Exposure of miners to high concentrations of dust and noise may cause occupational health hazards like pneumoconiosis and noise induced hearing loss and other allied health risk. Health risk to miners from dust depends on dust size, concentration and duration of exposure whereas noise induced hearing loss depends on sound pressure level, frequency and exposure level of workers. Exposure of workers to dust concentrations and sound pressure levels beyond threshold limit values as prescribed limits by statutory enactments and guidelines may adversely affect the health of mine workers. To assess the status of dust concentrations and noise levels generated by various machines and exposure levels of workers, conduct of systematic dust and noise survey in mines is essential. It will help in assessing the situation vis-a-vis dust and noise standards so that effective dust and noise control strategies can be adopted to minimize their menace.

Keeping this in view, this project work was undertaken to carry out dust and noise survey in an iron ore mine of SAIL. The objectives of the project work are as follows:

1.1 Objectives of the Project

- To conduct dust survey in Bolani opencast iron ore mine
- To conduct noise survey in Bolani opencast iron ore mine.
- To assess the status of noise level and dust concentration in mine vis-a-vis prescribed standards
- To propose appropriate dust and noise control measures based on the survey conducted and
- To apply Fuzzy Logic Toolbox for the computation of Noise Rating (NR).

CHAPTER: 02
LITERATURE REVIEW

CHAPTER: 02
LITERATURE REVIEW

2.1.1 MINE DUST

Dust is an ancient term used to describe fine particles that are suspended in the atmosphere. The term is non-specific with respect to the size, shape and chemical make-up of the particles. Particles having size ranging from few nanometres to 100 microns are measured in the atmosphere. Generally dust is formed when fine particles become entrained in the atmosphere by the turbulent action of wind, by the mechanical disturbance of fine materials, or through the release of particulate-rich gaseous emissions. Mostly concentration of particles in the atmosphere can range from a few micrograms to hundreds of micrograms per cubic metre ($\mu g/m^3$) in highly polluted areas.

Dusts which are associated with mining activity usually occur as a result of the disturbance of fine particles derived from soil or rock. Its formation is initiated by the disturbance of particles through mechanical action e.g.; blasting, handling, transporting, in combination with air movement. Particles are small and light, with a high surface area relative to their mass, the upward forces exerted on particles by air movement may exceed downward gravitational forces, leading to the formation of dust.

Depending on factors such as climate, geology and the method of mining etc., the potential exists for greatly increased dust levels in the environment surrounding a mine. Modern methods of mining often involve the mining, transport and handling of huge tonnages of material, increasing the potential for dust to be produced. The consequences generally include visible plumes and haze, the staining and soiling of surfaces, aesthetic or chemical contamination of water bodies or vegetation and, effects on personal comfort, amenity and health.

Mine dusts are qualitatively quite different to other types of dust. In an urban environment, dust commonly includes sources from industry, transport, land clearing and wood smoke. Mine dust is typically less complex in its make-up, consisting mainly of particles from exposed soil and rock.

Mine dust can result into a serious nuisance and loss of amenity for populations living in the vicinity of a mine. This may be exacerbated by certain types of dust, such as coal and iron ore dust that are highly visual and may result in a prominent and unsightly coating over surfaces.

Dust rarely presents a serious threat to the wider environment. Dust concentrations, and hence deposition rates and potential impacts, tend to decrease rapidly away from the source. In the majority of situations dust produced by mining operations is chemically inert, although exceptions may occur where dust particles contain phytotoxic substances such as cement dusts or fluorides. Damage to vegetation and agriculture is possible through mechanisms such as the blocking of leaf stomata or reduced photosynthesis due to smothered surfaces. While such effects on vegetation are likely to be localised and reversible, they can contribute to negative public perceptions of the mining operation's environmental performance. Nevertheless, there does exist the potential for harmful and more persistent contamination of the wider environment from certain types of material that may be exposed by mining. Dust derived from ore types containing asbestos, radioactive materials or heavy metals, for example, are in this category.

2.1.2 THE TERMINOLOGY ASSOCIATED WITH DUST

Common terminology used to describe different classes of dust includes:

• **Nuisance dust**

It is a term generally used to describe dust which reduces environmental amenity without necessarily resulting in material environmental harm, comprising particles with diameters nominally from about 1 mm up to 75 µm (micron), produced through the crushing and abrasion of materials.

The TSP range of dust particles is broad, and may be produced from sources such as industrial and mining processes, agricultural practices and, from wind erosion of the natural environment. Impacts of mine dust on near neighbours are most often due to nuisance dust.

• **Fugitive dust**

It refers to dust derived from the mechanical disturbance of granular material exposed to the air or not easily defined sources. Dust produced from these open sources is termed "fugitive" because it is not discharged to the atmosphere in a confined flow stream. Common sources of fugitive dust include unpaved roads, agricultural tilling operations, aggregate storage piles, and heavy construction operations. Mine dust commonly is derived from such non-point sources.

For the above sources of fugitive dust, the dust-generation process is caused by 2 basic physical phenomena:

1. Pulverization and abrasion of surface materials by application of mechanical force through implements.

2. Entrainment of dust particles by the action of turbulent air currents, such as wind erosion of an exposed surface by wind speeds over 19 kilometres per hour (km/hr.).

• **Inhalable dust**

It is the mass fraction of the total airborne particles which are inhaled through the mouth and nose are termed as inhalable dust. These particles are generally less than 10 mm in diameter and approximately 80% of these particles are between 2.5 and 10mm in diameter. Once inhaled these particles are deposited are deposited in the trachea and bronchia section of the lung.

•**Respirable dust**

It is that mass fraction of inhaled particles which penetrates to the lung's unciliated airways, represents those particles with diameters less than 2.5 mm that lodge in the alveolar region of the human lung.

•**Total suspended particulates (TSP)**

The nominal size of this fraction has particles with a diameter up to 50 microns. The monitoring program for TSP follows AS 2724.3—1987. This enables a determination of dust concentrations in units of mass (usually micrograms) per cubic metre.

• **Particulate matter less than 10 microns in size (PM10) or 2.5 microns (PM2.5)**

This dust fraction involves particles with a diameter up to 10 microns or 2.5 microns, respectively. Measurements are also expressed in units of mass (Usually micrograms) per cubic metre. The monitoring program for PM10 follows AS 3580.9.6—1990. PM10. There is no Australian Standard for measuring PM2.5, and this unit is not commonly applied in measuring ambient dust associated with mining.

• **Deposited matter**

This term describes any particulate matter that falls out from suspension in the atmosphere. The monitoring program follows AS 3580.10.1—1991. This measurement is usually expressed in units of mass per area per time.

2.1.3 SOURCES OF DUST IN MINES

A wide range of mining activities can produce dust. Dust sources may be localised, from blasting, truck loading, and ore crushing and conveyor transfer within the process plant. These sources are usually visible and readily identifiable. They are mostly from a direct result of mining and processing activities involving some form of ground disturbance or mechanical handling of the mined materials. Other sources of dust around the mine site are more diffuse, typically arising from relatively large areas such as waste rock dumps, pits, tailings impoundments and miscellaneous areas of disturbed and bare ground in and around the site. Linear dust sources are another category, which comes from haul roads as a common example. All of the above are categorised as fugitive dust emissions sources, in contrast to point source emissions from a stationary vent stack. Mining activities produce mostly fugitive dust.

2.1.4 HEALTH HAZARDS OF MINE DUST

Health risks caused by inhaled dust particles are influenced by both the penetration and deposition of particles in the various regions of the respiratory tract and the biological responses to these deposited materials. The smaller the particles, further they penetrate the respiratory tract. The largest particles are deposited mostly in the nasal passages and throat. Much smaller particles, nominally less than 2.5 µm (PM2.5), reach the deepest portion of the lungs.

Studies have linked levels of ambient particulate matter with a variety of human health problems, including mortality, increased hospital admissions and changes to the respiratory system. These effects have been observed through both short term (usually in days) and long term (usually in years) exposure.

2.1.4.1 Human respiratory system

The airborne dusts mostly enter the body by inhalation, but depending upon the particle size only some of the inhaled particles are deposited in the respiratory system and remaining parts are either gets expelled or swallowed. Few particles are removed from these deposition sites by clearance mechanisms, while those that remain behind may react within the lung to produce local injury. Soluble particles enter the bloodstream and may be carried to a remote susceptible organ. Particle size and other physico-chemical characteristics largely determine where, and what fraction of particles is deposited. Understanding the process by which inhaled particles are deposited in the lung requires knowledge of the structure of the human respiratory system.

Main purpose of the lungs is to supply oxygen needed by the body's cells and to remove carbon dioxide, a waste product produced as cells use oxygen. This process is referred to as gas exchange. As shown in Figure 2.1, air entering through the nose or mouth passes immediately into the pharynx and then into the larynx, or voice box. After this point, the air enters the trachea, or windpipe, the beginning anatomical structure of the lung, which eventually divides into the right and left bronchi. The bronchi divide into successively smaller branches called bronchioles, whose total cross-sectional area increases with progression down the respiratory tract. The trachea, bronchi, and larger bronchioles are lined with a mucous membrane whose outermost cells are covered with cilia. The cilia, minute hair-like structures, constantly lash back and forth in the mucus, which moistens the airway walls. This process is called mucociliary action. This action physically carries deposited debris out of these lung areas.

Beyond the terminal bronchioles are alveolar structures whose walls contain indentations, alveoli, 150-400 micrometres in diameter. The walls of the alveoli contain pulmonary capillaries within which the oxygen and carbon dioxide exchanges occur.

In a healthy adult there are approximately 300 million alveoli in the respiratory system, along with 14 million alveolar ducts. The total alveolar surface varies between 30 and 80 square meters, depending on individual factors such as age, sex, body structure, and state of health. Because of the delicacy and complicated structure of the thin walls that separate the alveolar air spaces from the bloodstream, the lungs are extremely vulnerable to airborne substances. The majority of the coarser airborne particles may be deposited in the winding passages through which the air must pass and may be removed by ciliary clearance action along these airways. However, these defences may be compromised for a variety of reasons, including particle overload. As particles accumulate in the respiratory tract, inflammation and other adverse responses may occur, potentially progressing to disease.

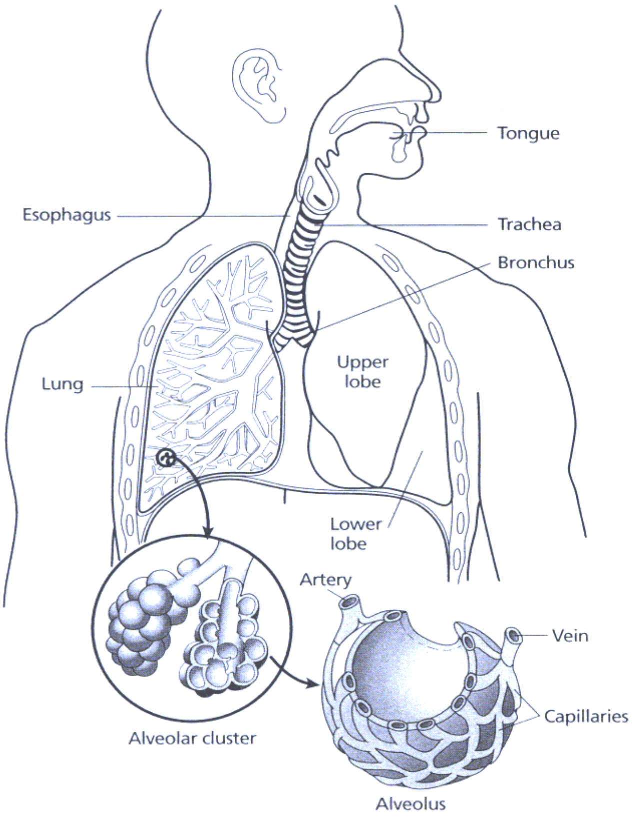

Fig. 2.1 Human respiratory system

Source: *Occupational Health Program for Exposure to Crystalline Silica. First edition, March 1997. National Industrial Sand Association (NISA).*

2.1.5 DUST DISEASES

Silicosis: Main component of this disease is Silica (SiO_2) which is found mainly as quartz is nearly all mineral deposits. It is found in common rock such as granite, sandstone, limestone and is the principle component of sand. Its severity depends upon mainly: the dust concentration, the percentages of free silica, duration of the exposure time into the environment and the size of the respirable dust particles. Its characterisation can be done at different stages as follows:

1st stage: Dyspnoea (inelasticity) of the lung, shortening of breath is noticed on exertion, dry cough and Radiograph show discrete circular shadows of nodules of 2mm dia.

2nd stage: well established dyspnoea & cough with impaired chest expansion and Radiograph shows diffuse nodulation with a tendency to coalescence.

3rd stage: Dyspnoea leads to total incapacity, Radiograph shows massive consolidation.

Asbestosis

All types of asbestos have tendency to break into very tiny fibres. These individual fibres are very small, must be identified using a microscope. Some fibres may be up to 700 times smaller than a human hair because asbestos fibres are so small, once released into the air, they may stay suspended there for hours or even days. Its fibres are also virtually indestructible. They are resistant to chemicals and heat, and they are very stable in the environment. They do not evaporate into air or dissolve in water, and they are not broken down over time. Asbestos is probably the best insulator known to man till date. Progress of fibrosis in asbestosis is more severe than silicosis. However, it makes the lung less susceptible to TB than silicosis one of the diseases associated with asbestosis is lung cancer and this usually occurs in the asbestos worker who smokes cigarettes. In fact the risk of the asbestos worker who smokes is 90 times more likely than the non-asbestos, non-smoking worker.

Symptoms

Shortness of breath and a dry crackling sound in the lungs while inhaling cough sputum & weight loss and in its advanced stages, the disease may cause cardiac failure.

Anthracosis

Inhalation of coal dust is the main reason for this disease in the mine.others reason are relatively fewer occurrences in low-rank coal mines compared to anthracite mines, Vitrain in low rank coals contains antibiotics. Its effects can be severely disabling, causing pulmonary emphysema or chronic bronchitis. Cigarette smoking is known to make the symptoms worse.

Symptoms

Anthracosis may be asymptomatic. Early symptoms of the disease include shortness of breath, laboured breathing, coughing with coal-black sputum, emphysematous chest.

At this stage, avoiding exposure to coal dust can stop the disease.

Siderosis

This disease is mainly caused by the long-term exposure to iron dusts or fumes.

Symptoms

Chronic bronchitis, emphysema and shortness of breath upon exertion. Penetration of iron particles in the skin or eye may cause an exogenous or ocular siderosis which may be characterized by a red-brown pigmentation of the affected area. Ingestion overexposures to iron may affect the gastrointestinal, nervous, and hematopoietic system and the liver.

2.1.6 DUST SAMPLING METHODS

2.1.6.1 Filtration: It has become important in recent times owing to its adoption of the mass conc. of the respirable size fraction as the relevant dust parameter signifying hazard.

Instruments

Gravimetric Dust sampler

SIMPEDS (Safety in Mines Personal Dust Sampler)

SIMQUADS (Safety in Mines Quarry Dust Sampler)

Fig. 2.2 Gravimeter dust sampler (www.bgiusa.com)

Fig. 2.3 Personal dust sampler (www.envirotech.tradeindia.com)

2.1.6.2 SEDIMENTATION

Certain volume of air is caught in a vertical cylinder and the dust allowed to settle by gravity on to a glass slide placed at the bottom of the cylinder .After that the slides are examined under the microscope for determining particle conc. and size Method has been claimed to give 100% efficiency for particles >0.2μm size, but requires a long-time of settling under rigorous laboratory conditions.

Drawbacks:

a. Tedious microscopic counting and sizing
b. Subject to personal error

2.1.6.3 INERTIAL PRECIPITATAION

Inertial Precipitation Method is based on three principles:

Impaction: In this method the dust are automatically get deposited to the instrument as the instrument is kept in the dust atmosphere and after that concentration of the dust are measured directly through the reading on the scale. Most common example of this type of dust sampler is Konimeter (1916 Sir Robert Kotze) (improved version by Carl Zeiss,1937)

Impingement: In this type of method of sampling the dust gets impinged to the instrument. Most common example of this type of sampler is Midget impinge (commonly used in USA)

Centrifuging: In this type of dust sampling method the dust particles are deposited on the sampler as a result of the centrifugal action. Most common example for this type of sampler is the centrifuge developed by Sawer and Waltson.

2.1.6.4 THERMAL PRECIPITATION

When a body get surrounded by dusty air is heated, a dust free zone is produced around the hot body; the extent of the dust-free zone depends on the temperature gradient between the hot body and the surrounding air and if such a zone is intercepted by two glass cover slips and a current of dusty air allowed entering the space between them in the direction, the dust in the air gets deposited on the cover slips where it remains attached by molecular attraction.

After that the sample has been collected on the cover slips and the latter are mounted on a microscope slide and waxed to it so that the dust enclosed between two glass surfaces.

The slide is then counted under a high power microscope and then counting is done with the help of a suitably calibrated gratitude introduced in the eye piece.

2.1.6.5 ELECTRICAL PRECIPITATION

Electrical Precipitation essentially consists of a charging wire maintained at a high negative potential of about 12,000 volts and surrounded by an earthed concentric cylinder Dust-laden air is drawn through the cylinder by a fan at a constant rate. The dust particles when passing through the instruments get charged and are drawn to and precipitated on the inner surface of the earthed cylinder. The instrument, like filtration devices, has a large sampling capacity and is suitable for collecting large quantities of dust for chemical analysis

Mass conc. can also be determined by noting the difference in wt. of the cylinder before and after collection of dust Instruments based on this principle has high collection efficiency,

But the high voltage requirement makes it unsuitable for coal mines.

2.1.6.6 OPTICAL METHODS

The method uses the property of scattering of light by a suspension of fine particles. For particles large enough compared to the wave length of light, i.e. particles above 1µm in diameter, the intensity of scattered light is roughly given by

$$I_S / I_O = KND^2 \text{ -- } (1)$$

Where

Is= intensity of scattered light

I_0 = intensity of incident light

N = No. of particles per unit volume

D = diameter of particles

K = constant depending on the refractive index, absorption co-efficient and the shape of particles as well as the wave length of light, angle of scattering and the distance of the point of observation from the dust cloud.

For particles smaller than the wave length of light,

Rayleigh's law: $I_s \alpha D^6$ holds good.

In poly disperse dust clouds in mines, the intensity of light scattered by the large particles is so high compared to that by fine particles that the law of scattering light as given in equation (1) can be easily adopted for such clouds .The equation shows that the intensity of scattered light is proportional to the surface area of the particles. The 1st instrument based on this principle was the Tyndal meter designed by Tolman and Vilet in 1919 where the intensity of light scattered at right angles to the incident beam is measured.

Today, Tyndalloscope is very commonly used German coal mines for routine dust sampling.

2.1.7 DUST MEASURING INSTRUMENTS

2.1.7.1SIMPEDS 70 Mk 2 and SIMQUADS

The elutriator-filter unit

Simpeds: mounted on the miner's helmet by the side of the lamp
Simquads: usually clipped to the jacket lappel of the miner

The pump unit

Simpeds: mounted on the cap lamp battery which supplies power to it.
Simquads: mounted on a three cell nickel-cadmium battery which can be strapped on to the belt of the miner.
Dusty air is sucked into the cyclone through its inlet. The course fraction is deposited in the cyclone and collected in a grit spot & the respirable fraction of dust deposited in the underside of a 37mm membrane filter/glass-fibre filter repacked in a small plastic holder
The diaphragm pump maintains a flow rate of 1.85l/min through the sampler has a pulsation damper (for smoothening pulsating flow) and a flow indicator.

2.1.7.2 APM 800 PERSONAL RESPIRABLE DUST SAMPLERS (ENVIROTECH, NEW DELHI)

It has a NI-Cd rechargeable battery permitting 8Hr operation comprising of Teflon filter holder is located at the top of the cyclone and accepts a 37mm diameter filter disc. Respirable fraction of the air-borne dust is collected on the filter paper and weighed. Flow rate can be up to 3 L/min. The dimension of this instrument is 155 x 82 x 60mm and the Weight is: 1.3 kg. It does not have a certificate of intrinsic safety and hence can be used only in opencast mines or underground metalliferous mines.

2.1.7.3 SIMSLIN

First mine air is drawn into the device through a standard parallel plate elutriator. The respirable fraction of dust that remained is then passed through a collimated beam of near infrared radiation. A photomultiplier tube is used to detect the intensity scattered along the specified range of directions and electronic circuits produced a corresponding output current for display on an external recorder. The result shown is intended to be related to the concentration of respirable dust passing through the beam. On discharge, the dust is captured on a membrane filter for gravimetric assessment or composition analysis.

2.1.8 DUST SURVEY

In order to do a systematic dust survey at the mine, the following guidelines are followed:

i) **Instruments:** first of all depending upon the different parameters, there are numbers of dust sampler to be used to conduct the air- borne survey
   a) NCB/MRE dust samplers of approved type 113A or its approved equivalent.
   b) Personal- samplers of approved types.
   c) Personal asbestos dust sampler of an approved type.
   d) Any other dust- sampler approved by DGMS.

ii) **Maintenance and calibration of the instruments:** The instrument should be properly maintained and systematically calibrated as per the manufacturer's instruction.

iii) **Laboratories for evaluation of the samples:** the laboratories for evaluation of the samples drawn and determination of its quartz content should be properly equipped.

iv) **Samplers:** trained persons should be appointed for the survey of the field.

v) **General sampling Procedure:** It contains different sampling procedures like sampling with MRE or its equivalent, sampling position, places to be sampled, and duration of sample, frequency of sampling, Quartz content, defective samples and recordings of the results.

2.1.9 DUST STANDARDS

- A permissible limit of exposure is developed based on the dust dose, duration of exposure and incidence of pneumoconiosis by most of the countries.
- In Indian mines the **Directorate of Mines Safety (DGMS), Govt. of India, has prescribed a dust concentration of 3 mg/m^3**.
- The sampling guidelines recommended the NCB/MRE GDS sampler, type 113A for monitoring of air borne dust in Indian mines and personal sampler giving same cut off characteristic curve as BMRC for assessment of dust dose of individual workers during work shift.

2.1.10 PREVENTION AND SUPPRESION OF DUST:

Generally it can be done on three levels

1. Prevention of the production of the dust
2. Prevention of the dust ,already formed ,getting air borne and
3. Dilution and suppression of the air-borne dust.

2.1.10.1 Prevention of the production of the dust

Dust is mainly produced by mining operations like drilling, coal cutting and blasting. Crushing of coal pillars by rock pressure is an important source of dust production.

Production of fine dust during drilling can be minimized by using sharp bits so that there is more of chipping than that of grinding action. Sufficient thrust on the bit and suitable arrangement for the clearance of cuttings from the hole help in reducing the dust production.

CCM should be used with sharp picks for minimizing the dust production in the mining operation.

For the blasting its production can be minimized by suitably controlling the hole patterns and the quantity and strength of the explosive keeping in the mind to avoid the fragmentation.

Free fall of material at the face, during transport and at transfer points should be reduced as far as possible. The system of haulage should be designed, installed and used with a view to minimize the spillage of the materials.

2.1.10.2 Prevention of dust getting air-borne

2.1.10.2.1 Drilling: Suppression of dust produced by drilling can be obtained mainly by adopting wet drilling. For wet drilling to be effective, the pressure of water should be sufficient, but too high a pressure reduces the rate of penetration by cushioning the cutting action and hence should be avoided. A good pressure is about 75 KPa less than the pressure of air (i.e. 400-500 KPa). The amount of water fed into the hole should be at least 3×10^{-3} m^3 min^{-1} for effecting proper dust suppression. Nowadays rotary drills have also been fitted with external flush-head for heads for water flushing through hollow drill steels.

Where water is scarce, foam can be used for suppressing dust. Foam is usually produced by adding a small quantity (uaually1%) of a foaming agent like pyrene to water.

2.1.10.2.2 Coal winning: Winning of coal by coal cutting machines, continuous miners or pneumatic picks produces a lot of dust. Dust produced by pneumatic picks can be reduced by about 50% by using wet pneumatic picks. Suppression of dust produced by coal-cutting machines is usually done by water sprays incorporated in the machine. There are usually four or five jets, 6mm in diameter provided at different parts of the jib for spraying the gummings at the source of production. These sprays are usually fed by internal water feed-pipes fitted inside the jib. The reduction of dust concentration by wet cutting varies between 80 to 90% of the dust produced by dry cutting.

2.1.10.2.3 Loading: Much dust can be raised by loading dry material. That is why it is desirable to wet the muck pile by water sprays before loading.

2.1.10.2.4 Water infusion: Cleavages and racks in coal seams usually contain a large quantity of fine dust which is set free during the process of winning. Such dust can be suitably allayed by infusing the coal with water under pressure. Usually holes 50mm in diameter and 1.8m long are drilled at 3 to 5m interval along a face. The holes should be drilled at right angles to the cleavage planes; thus it may be necessary to drill holes inclined to the face (flanking holes). In British coal mines, water infusion has been claimed to achieve about 75% reduction in the dust concentration at the face. In addition to suppressing dust, water infusion loosens the coal to some extent, thus making its winning easier.

2.1.10.2.5 Pulsed infusion: The loosening of coal with water infusion led to the development of pulsed infusion. Here, a pulse or shock is imparted to the water in the hole by firing an explosive charge in it so that the loosening effect is enhanced in addition to suppressing dust. Flanking holes inclined at an angle of 0.8 rad to the face are commonly used for pulsed infusion. They are about 2-3.5m long and spaced at 1.8m intervals. The holes are first charged with the requisite quantity of explosive and then the infusion tube is inserted, the seal tightened and the hole infused with water under pressure for about 15-20 minutes before the shot is fired. Pulsed infusion may be sufficient to blast coal in the solid depending on the nature of coal, but it is also extensively used for blasting undercut faces. The amount of explosive used for solid blasting is about 250 to 350g/hole. Sometimes pulsed infusion with a lesser quantity of explosive (150-250g) may be done in the solid in order to loosen the coal ploughs or cutter-loaders. Long holes drilled parallel to the face at a distance 1.5m have been fired by pulsed infusion.

2.1.10.2.6 Water stemming: This consists of stemming a shot hole after charging with a plastic or P.V.C. bag (usually 0.15mm thick) filled with water. Water, owing to its incompressibility, gives a better confinement to the charge so that a better efficiency of blasting is obtained. This usually results in a saving of about 25% in the explosive consumption. Water stemming produces less dust, the reduction in the dust concentration being 50-70% of the dust produced by blasting with ordinary clay stemming.

2.1.10.2.7 Removal of deposited dust: Often, dust deposited on the floor of mine roadways can become air-borne by high velocity air-current, trampling by men etc. A vacuum-cleaning device has been designed for removing the dust deposited on roadways. The dust is delivered first to a cyclone for the separation of coarse particles and then to a filter for collecting the finer dust.

2.1.10.2.8 Consolidation of roadway dust: The best method of preventing roadway dust getting air-borne is to consolidate it. The simplest method of consolidation is by wetting the dust with water sprays, but water sprays alone do not produce good wetting of all deposited dust and a large quantity of water may be needed for producing effective results. Besides, water evaporates quickly needing very frequent spraying. Two common methods of consolidating roadway dust are:-

1. **Calcium Chloride method**
2. **Salt Crust Process**

2.1.10.2.8.1 Calcium Chloride Method

This method utilized the principle of keeping the dust constantly and thoroughly wetted so that it takes on the consistency of a paste. To this end, the dust is first sprayed with water mixed with a suitable wetting agent and then sprinkled over with calcium chloride. Calcium chloride, being hygroscopic, absorbs moisture from the air and keeps the dust wet. Subsequent trampling by men further helps in the consolidation of the dust. The amount of calcium chloride depends on the relative humidity of the air and generally varies between 2 to 7% of the dust. A single treatment lasts for a period which may be anything from a couple of months to a year depending on the rate of deposition of dust. The method is unsuitable for a heavy rate of deposition so that it becomes imperative to use this method of consolidating roadway dust only in conjunction with suitable suppressive measures adopted at the face and other points of dust generation.

2.1.10.2.8.2 Salt Crust Process

Here, unlike the calcium chloride method, the dust is bound up in the form of a crust. The method consists of sprinkling common salt on the dust and then spraying it with water. Initially water amounting to about 15% of the weight of the salt used is sprayed. The salt dissolves and penetrates into the dust, but soon, the water starts evaporating, thus causing the salt to recrystallize and form a hard crust on the surface. Particles of dust are trapped in the growing salt crystals and thus consolidated. As fresh dust is deposited on the crust, it becomes necessary to re-spray it so that the salt can dissolve and recrystallize entrapping the freshly deposited dust. The amount of water to be sprayed subsequently should be such that it ensures a high rate of crystallization, maintaining at the same time a firm crust. The salt crust process has been found to be unsuitable for very high (>75%) and very low (<55%) humidity and because of this many German mines are now using the calcium chloride process.

2.1.10.3 DILUTION AND SUPRESSION OF AIR-BORNE DUST

The simplest way of reducing the concentration of dust in air to a pathologically safe limit is to dilute it by increasing the quantity of ventilation. But large concentration would require a large quantity of air which will increase the cost of ventilation and also create high air velocities which may raise deposited dust. Suppression of air-borne dust, can be classified into two methods:-

1. **Wet suppression**
2. **Dry suppression**

2.1.10.3.1 Wet suppression

Wet dust suppression systems use liquids (usually water) to wet the material so that it has a lower tendency to generate dust. Keeping the material damp immobilizes the dust, and very little material becomes airborne. This technique suppresses airborne dust by spraying fine droplets of water on the dust cloud. The water droplets and dust particles collide and form agglomerates. Once these agglomerates become too heavy to remain airborne, they settle from the air stream. Wet dust suppression systems wet the entire product stream so that it generates less dust. This also prevents dust from becoming airborne. Effective wetting of the material can be achieved by-

Static Spreading - The material is wetted while stationary. The diameter and contact angle of water droplets are important factors in static spreading.

Dynamic Spreading - The material is wetted while moving. The surface tension of the liquid, the droplet diameter, the material size, and the droplet impact velocity are important variables in dynamic spreading.

Types of Wet Dust Suppression Systems: Wet suppression systems fall into three categories:

1. **Plain Water Sprays** - This method uses plain water to wet the material. However, it is difficult to wet most surfaces with plain water due to its high surface tension.
2. **Water Sprays with Surfactant** - This method uses surfactants to lower the surface tension of water. The droplets spread further and penetrate deeper into the material pile.
3. **Foam** - Water and a special blend of surfactant make the foam. The foam increases the surface area per unit volume, which increases wetting efficiency.

2.1.10.3.2 Dry dust suppression

This usually consists of exhausting the dusty air from the point of operation and then separating the dust from the air by inertial separation, filtering, electrical precipitation etc. so that cleaned air can be re-circulated. Means of dry dust suppression are commonly used in mines at transfer points, ore bin, and crusher stations and even for cleaning the air after blasting in headings.

2.2 NOISE SURVEY IN MINES

2.2.1 BASIC TERMINOLOGY OF NOISE:

- **Sound and Noise**

Sound is what we hear through our ear out of which noise is unwanted sound. Sound is a form of energy which is emitted by a vibrating body which on reaching the ear causes sensation of hearing through nerves. Sounds produced by all vibrating bodies are not audible. The frequency limits of audibility are from 20 Hz to 20 KHz. A noise problem generally consists of three inter-related elements- the source, the receiver and the transmission path. This transmission path is usually the atmosphere through which the sound is propagated, but can include the structural materials of any building containing the receiver.

Noise may be continuous or intermittent. Noise may be of high frequency or of low frequency which is undesired for a normal hearing. The discrimination and differentiation between sound and noise also depends upon the habit and interest of the person/species receiving it, the ambient conditions and impact of the sound generated during that particular duration of time.

- **Decibel**

The decibel (dB) is a logarithmic unit of measurement that expresses the magnitude of a physical quantity (usually power or intensity) relative to a specified or implied reference level. Since it expresses a ratio of two quantities with the same unit, it is a dimensionless unit. A decibel is one tenth of a bel, a seldom-used unit. The decibel can be expressed as:

$$\textbf{Decibel} = 10 \log (P / P_{ref})$$

Where, **P** = signal power (W)

P_{ref} = reference power (W)

- **Sound Power Level**

Sound power is the energy rate - the energy of sound per unit of time (J/s, W in SI-units) from a sound source. Sound power can be expressed as a relation to the threshold of hearing - 10-12 W - in a logarithmic scale named Sound Power Level - L_w:

$$L_w = 10 \log (N / No) \qquad (2)$$

Where, L_w = Sound Power Level in Decibel

N = sound power (W)

The lowest sound level that people of excellent hearing can discern has an acoustic sound Power about 10-12 W, 0 dB. The loudest sound generally encountered is that of a jet aircraft with a sound power of 105 W, 170 dB.

- **Sound Intensity Level**

Sound Intensity is the Acoustic or Sound Power (W) per unit area. The SI-units for Sound Intensity is W/m^2.

The Sound Intensity Level can be expressed as:

$$L_I = 10 \log (I / I_{ref}) \qquad (3)$$

Where L_I = sound intensity level (dB),

I = sound intensity (W/m^2),

$I_{ref} = 10^{-12}$ reference sound intensity (W/m^2)

- **Sound Pressure Level**

Sound pressure converted to the decibel scale is called sound pressure level (L_p). The zero of the decibel scale (0 dB) is the sound pressure of 0.00002 Pa. This means that 0.00002 Pa is the reference sound pressure to which all other sound pressures are compared on the dB scale. This is the reason the decibels of sound are often indicated as dB re 0.00002 Pa. The SI-units for the Sound Pressure are N/m^2 or Pa

The Sound Pressure Level:

$$Lp = 10 \log(p^2 / p_{ref}^2) = 10 \log(p / p_{ref})^2 = 20 \log (p / p_{ref}) \qquad (4)$$

Where **Lp** = sound pressure level (dB)

p = sound pressure (Pa)

p_{ref} = 2 x 10-5 - reference sound pressure (Pa)

If the pressure is doubled, the sound pressure level is increased with 6 dB (20 log (2)).

- **A-weighted decibels**

Sensitivity of the human ear to sound depends on the frequency or pitch of the sound. Some people hear some frequencies better than others. If a person hears two sounds of the same sound pressure but different frequencies, one sound may appear louder than the other. This occurs because people hear high frequency noise much better than low frequency noise.

Noise measurement readings can be adjusted to correspond to this peculiarity of human hearing. An A-weighting filter which is built into the instrument de-emphasizes low frequencies or pitches. Decibels measured using this filter are A-weighted and are called dB(A). Legislation on workplace noise normally gives exposure limits in dB (A). A-weighting serves two important purposes:

1. Gives a single number measure of noise level by integrating sound levels at all frequencies
2. Gives a scale for noise level as experienced or perceived by the human ear.

- **Frequency analysis**

It is measuring noise level at each frequency or pitch. Frequency analysis is not required when the purpose of noise measurement is to assess compliance with regulatory exposure limits or to assess risk of hearing loss. For such purposes the A-weighted noise level in dB (A), percent noise dose or time-weighted average (TWA) equivalent sound level is sufficient. The frequency analysis is usually needed only for the selection of appropriate engineering control methods.

Sometimes it is necessary to determine the actual frequency distribution of the noise. A detailed frequency analysis is called narrow band analysis. In this method the entire audible frequency range is divided into frequency windows of fixed width of a few hertz and noise level is measured in dB units at each of these frequency windows. Narrow band analysis is normally not needed for workplace noise. Such analysis is used for engineering measurements. For workplace noise we need octave band analysis.

Octave bands are identified by their centre frequency. The band width increases as the centre frequency increases. The audible sound frequency range (approximately 20 to 20,000 Hz) has been divided into 11 octave bands for this purpose. An octave band filter set can be attached to an SLM to measure the sound level in each octave band.

2.2.2 HEARING MECHANISM OF HUMAN EAR:

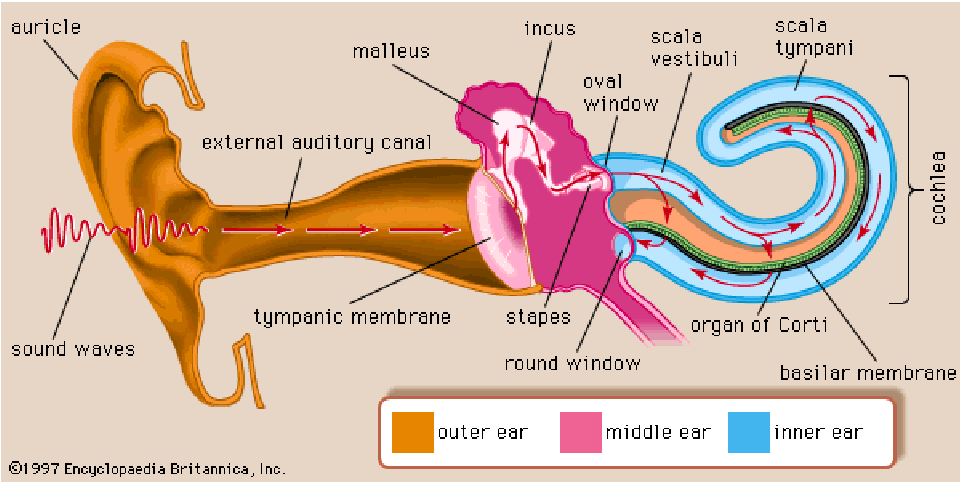

Fig 2.4 Human ear

Source: http://www.britannica.com/EBchecked/media/536/The-mechanism-of-hearing

The ear can be divided into three parts: the outer, middle, and inner ear (figure 2.5). Each of these parts plays a different part in transmitting sound to the brain. The outer ear collects sound waves and causes the eardrum to vibrate. The middle ear has three small bones (the hammer, anvil, and stirrup) connected to the eardrum. As our eardrum vibrates, these bones vibrate, too. The bones transmit their vibrations to the inner ear where they end up at a special snail-shaped structure called the cochlea. The cochlea is a rolled-up, tapered canal that is filled with fluid. The vibrations cause the fluid in the cochlea to vibrate (bend back and forth). This in turn causes tiny hair cells in your ear to vibrate. When the hair cells bend (vibrate), it is converted into an electrical impulse by the auditory nerve. The impulses travel along nerves to the brain, where they are translated into the sensation of hearing or sound.

The hair cells respond to noise vibrations in two basic ways:

1. Only certain hair cells bend to any particular frequency of sound. Thus, hair cells respond only to the frequency to which they are sensitive.
2. The amount of bending the hairs undergo depends on how much energy (decibels) the noise has—the greater the energy, the more bending that takes place (i.e., the louder the noise will sound).

2.2.3 EFFECTS OF NOISE ON HUMAN HEALTH

How noise affects will depend upon how long we are exposed to a sound, the loudness of the sound, and the ability of our body to recover after that exposure.

- **Annoyance:** It creates annoyance to the receptors due to sound level fluctuations. The aperiodic sound due to its irregular occurrences causes displeasure to hearing and causes annoyance.
- **Physiological effects:** The physiological features like breathing amplitude, blood pressure, heart-beat rate, pulse rate, blood cholesterol are effected.
- **Loss of hearing:** Long exposure to high sound levels cause loss of hearing. This is mostly unnoticed, but has an adverse impact on hearing function.
- **Human performance:** The working performance of workers/human will be affected as they'll be losing their concentration.
- **Nervous system:** It causes pain, ringing in the ears, feeling of tiredness, thereby effecting the functioning of human system.
- **Sleeplessness:** It affects the sleeping there by inducing the people to become restless and lose concentration and presence of mind during their activities
- **Damage to material:** The buildings and materials may get damaged by exposure to infrasonic / ultrasonic waves and even get collapsed.
- **Temporary threshold shift:** Temporary threshold shift (*TTS*) is a temporary loss of hearing. If we are exposed to a very noisy job, by the end of the shift we may have noticed a loss of hearing sensitivity. The greatest portion of temporary hearing loss occurs within the first two hours of exposure.

  The hair cells in our inner ear become exhausted from the excessive noise exposure and require more energy (decibels) before they will bend and send nerve impulses to the brain. This effect is “temporary” because the hair cells get a chance to rest while we are away from work, and by the next morning, they have recovered their sensitivity.
- **Permanent threshold shift:** Permanent threshold shift is a permanent hearing loss that is very similar to the pattern of temporary hearing loss, except that we do not recover. Some of the hair cells are physically destroyed by the constant pounding and bending, leading to nerve loss. The more exposure to loud noise, the more hair cells is destroyed. This eventually leads to total deafness. Permanent loss does not respond to any known treatment or cure.

- **Tinnitus:** Tinnitus is a ringing in the ears, similar to high-pitched background squealing with TVs and computers. It may accompany temporary and permanent hearing loss. Tinnitus is most noticeable in quiet conditions (e.g., sleeping at night) and may be a warning signal of permanent hearing loss.
- **Non-Auditory Effects:** Noise can affect more than just our hearing. First of all, the psychological effects of noise induced hearing loss can be distressing Noise can be a major cause of stress, adding to nervousness and anxiety. Noise may increase the heart rate and raise blood pressure by constricting blood vessels. Noise exposure can produce a permanent increase in blood pressure leading to heart disease.
- **Presbycusis:** Presbycusis is a hearing loss as a result of aging. Its onset and the amount of damage vary among people. It usually begins around age 50. Some people may never have hearing loss from Presbycusis. Family/genetic factors influence the extent of the loss. Presbycusis can be accelerated by noise exposure.

2.2.4 NOISE MEASUREMENT

2.2.4.1 Noise Measuring Instruments

The most common instruments used for measuring noise are the sound level meter (SLM), the integrating sound level meter (ISLM), and the noise dosimeter. When we use, it is important that we should understand the calibration, operation and reading the instrument.

2.2.3.1.1 Sound Level Meter (SLM)

A Sound level meter is the simplest instrument available to determine noise levels. The meter usually contains the following basic elements:

(a) A microphone to sense the sound-wave pressure and convert pressure fluctuations into an electrical voltage,

(b) An input amplifier to raise the electrical signal to a usable level,

(c) A weighting network to modify the frequency characteristics of the instruments,

(d) An output amplifier,

(e) A rectifier to determine the RMS value, and

(f) An indicating instrument to display the measured sound level.

The SLM must be calibrated before and after each use. With most SLMs, the readings can be taken on either SLOW or FAST response. The response rate is the time period over which the instrument averages the sound level before displaying it on the readout. Workplace noise level measurements should be taken on SLOW response. Impulse characteristics and peak-hold features are sometimes provided as special features.

To take measurements, the SLM should be held at arm's length at the ear height for those exposed to the noise. With most SLMs it does not matter exactly how the microphone is pointed at the noise source. The response rate is the time period over which the instrument averages the sound level before displaying it on the readout. Workplace noise level measurements should be taken on SLOW response.

A standard SLM takes only instantaneous noise measurements. This is sufficient in workplaces with continuous noise levels. But in workplaces with impulse, intermittent or variable noise levels, the SLM makes it difficult to determine a person's average exposure to noise over a work shift. One solution in such workplaces is a noise dosimeter.

Fig.2.5 CEL-283 sound level meter

(Source: www.casellausa.com)

Specification

Accuracy: Sound level meter: IEC 651, BS 5969 and ANSI S1.4 in the type 2 category. DIN 45 634 Maximum RMS hold and energy average as Leq, Lim or LTm (3 or 6 second), 40dB .Dynamic range linear scaled meter.

Ranges: 30 - 70 dB, 60 - 100 dB and 90 - 130 dB Overload indicator provided.

Measuring Limits: Self-noise less than 25dB (A) or less than 40dB (Flat).135dB absolute maximum.

Microphone: 17 mm (0.67 inch) electret condenser type

Frequency Response: dB (A) or Flat

Display: 47 mm (1.9 inch) meter movement covering 40 dB dynamic range.

Time Weightings: Fast, Slow and Impulse as per standards.

Maximum Hold: Analogue hold of maximum RMS level with a decay rate of less than 1 dB/5 min at 20ºC.

LEQ Calculation: By means of 10msec samples of RMS level. Minimum measurement duration 1 second, maximum greater than 24 hours.

Calibration: Field calibration checks by means of CEL-184 or CEL-182 Acoustic Calibrators (NB coupler type CEL-3379 necessary for X version).

Auxiliary Output: 3.5 mm jack feed of conditioned AC output at 1.0V for FSD via 3k3 Ohms.

Batteries: 3 x 6 F22 (or equivalent) - 2 for sound level meter and one for calibrator.

Temperature Range: 10 to +50ºC operational. -15 to +60ºC storage.

Humidity Range: 30% to 90% for ±0.5 dB

Electromagnetic Interference :< MSD for 400 A/M

Vibration Interference :< 62 dB (Flat) for 1 m/sec/sec

Dimensions: 235mm x 75mm x 54mm (9.2in x 3in x 2.1in)

2.2.3.1.2 Integrating Sound Level Meter (ISLM)

The integrating sound level meter (ISLM) is similar to the dosimeter. It determines equivalent sound levels over a measurement period. The major difference is that an ISLM does not provide personal exposures because it is hand-held like the SLM, and not worn. The ISLM determines equivalent sound levels at a particular location. It gives a single reading of a given noise, even if the actual sound level of the noise changes continually. It uses a pre-programmed exchange rate, with a time constant that is equivalent to the SLOW setting on the SLM.

2.2.3.1.3 Noise Dosimeter

It is a small, light device that can be clipped to a person's belt with a small microphone that fastens to the person's collar, close to an ear, stores the noise level information and carries out an averaging process. It requires the following settings:

(a) Criterion Level: Exposure limit for 8 hours per day five days per week. Criterion level is 90 dB(A) for many jurisdictions, 85 dB(A) for some and 87 dB(A) for Canadian federal jurisdictions.

(b) Exchange rate: 3 dB or 5 dB as specified as in the noise regulation.

(c) Threshold: Noise level limit below which the dosimeter does not accumulate noise dose data. Wearing the dosimeter over a complete work shift gives the average noise exposure or noise dose for that person. This is usually expressed as a percentage of the maximum permitted exposure. If a person has received a noise dose of 100% over a work shift, this means that the average noise exposure is at the maximum permitted. For example, with a criterion level of 90 dB(A) and an exchange rate of 2 dB(A), an eight-hour exposure to 90 dB(A) gives a 100% dose. A four-hour exposure to 92 dB(A) is also a 100% dose, whereas an eight-hour exposure to 92 dB(A) is a noise dose of 200%.

Dosimeters also give an equivalent sound or noise level. This is the average exposure level for noise over the time dosimeter was on. It has the same total sound energy as the actual, variable sound levels to which a person is exposed over the same time period. Scientific evidence suggests that hearing loss is affected by the total noise energy exposure. If a person is exposed over an eight-hour work shift to varying noise levels, it is possible to calculate an equivalent sound level which would equal the same total sound energy exposure. This would have the same effect on the person's hearing as the variable exposure actually received.

2.2.4 NOISE SURVEY

Most of the machines do not operate constantly or at a constant noise level. Exposure to noise varies due to mobility of workers, mobility of noise sources, variations in noise levels or a combination of these factors. Noise measurements should include max. and min, SPLs produced in dB(A) in any survey & all noise levels less than 80 dB(A) may be ignored. If the survey indicates that worker is exposed to noise >115 dB (A) then he should be provided with hearing protection. A noise survey takes noise measurements throughout an entire mines or section to identify noisy areas. Noise surveys provide very useful information which enables us to identify:

Areas where employees are likely to be exposed to harmful levels of noise and personal dosimeter may be needed,

1. Machines and equipment which produce harmful levels of noise,
2. Employees who might be exposed to unacceptable noise levels, and

3. Noise control options to reduce noise exposure.

Noise survey is conducted in areas where noise exposure is likely to be hazardous. Noise level refers to the level of sound. A noise survey involves measuring noise level at selected locations throughout an entire mines or sections to identify noisy areas. This is usually done with a sound level meter (SLM). A reasonably accurate sketch showing the locations of workers and noisy machines is drawn. Noise level measurements are taken at a suitable number of positions around the area and are marked on the sketch. The more measurements are taken, the more accurate the survey. A noise map can be produced by drawing lines on the sketch between points of equal sound level. The SLM must be calibrated before and after each use.

2.2.5 NOISE STANDARDS/ GUIDELINES

2.2.5.1 Ambient Noise Standards

Noise (ambient standards) published in the Gazette No. 643 dated 26.12.89, succeeded by The Noise pollution (Regulation and Control) rules, 2000 (Gazette of India, vide SO123(E), dated 14.2.2000 and subsequent amended vide SO 1046(E) dated, 22.11.2000).

Table 2.2 Noise standards

Area Code	Category of Area	Limits in dB(A)Leq	
		Day Time	Night Time
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Area	50	40

Note-1: Day time reckoned in between 6.00 am to 9.00p.m

Note 2: Night time reckoned in between 9.00p.m.to 6:00am.

Note 3: Silence zone is defined as areas up to 100 meter around such premises as Hospitals, Educational institutes and Courts. The Silence zones are to be declared by the competent Authority

Note 4: Mixed categories of areas should be declared as "one of the four above mentioned categories" by the Competent Authority and the corresponding standards shall be applied.

2.2.5.2 Work Place Noise Standards

DGMS Circular No.18 (Tech), 1975 A warning limit of 85-dB (A) may be set as the level below which very little risk to an unprotected ear of hearing impairment exists for an eight-hour exposure.

- The danger limit value shall be 90-dB (A) above which the danger of hearing impairment and deafness may result from an unprotected ear.
- A worker should not be allowed to enter, without appropriate ear protection, an area in which the noise level is 115-dB (A) or more.
- Personal protective equipment shall be worn, if there are single isolated outbursts of noise, which can go above 130-dB (A) "Impulse", or 120-dB (A) "Fast". ¨ No worker shall be allowed to enter an area where noise level exceeds 140-dB (A).

2.2.6 NOISE CONTROL

Noise generation is produced from most of our daily activities. A healthy human ear responds to a very wide range of SPL from - the threshold of hearing at zero dB, uncomfortable at 100-120 dB and painful at 130-140 dB Due to the various adverse impacts of noise on humans and environment noise should be controlled. The technique or the combination of techniques to be employed for noise control depend upon the extent of the noise reduction required, nature of the equipment used and the economy aspects of the available techniques.

The techniques employed for noise control can be broadly classified as:

- Control at source
- Control in the transmission path
- Using protective equipment

2.2.6.1 Noise Control at Source

The noise pollution can be controlled at the source of generation itself by employing techniques like-

- **Reducing the noise levels from domestic sectors:** The domestic noise coming from radio, tape recorders, television sets, mixers, washing machines, cooking operations can be minimised by their selective and judicious operation. By usage of carpets or any absorbing material, the noise generated from felling of items in house can be minimised.

- **Maintenance of automobiles:** Regular servicing and tuning of vehicles will reduce the noise levels. Fixing of silencers to automobiles, two wheelers etc., will reduce the noise levels.
- **Control over vibrations:** The vibrations of materials may be controlled using proper foundations, rubber padding etc. to reduce the noise levels caused by vibrations.
- **Low voice speaking:** Speaking at low voices enough for communication reduces the excess noise levels.
- **Prohibition on usage of loud speakers:** By not permitting the usage of loudspeakers in the habitant zones except for important meetings / functions. Now-a-days, the urban Administration of the metro cities in India, is becoming stringent on usage of loudspeakers.
- **Selection of machinery:** Optimum selection of machinery tools or equipment reduces excess noise levels. For example selection of chairs, or selection of certain machinery/equipment which generate less noise (Sound) due to its superior technology etc. is also an important factor in noise minimisation strategy.
- **Maintenance of machines:** Proper lubrication and maintenance of machines, vehicles etc. will reduce noise levels. For example, it is a common experience that, many parts of a vehicle will become loose while on a rugged path of journey. If these loose parts are not properly fitted, they will generate noise and cause annoyance to the driver/passenger. Similarly is the case of machines. Proper handling and regular maintenance is essential not only for noise control but also to improve the life of machine.

2.2.6.1.2 Control in the transmission path

The change in the transmission path will increase the length of travel for the wave and get absorbed/refracted/radiated in the surrounding environment. The available techniques are briefly discussed below.

Installation of barriers: Installation of barriers between noise source and receiver can attenuate the noise levels. For a barrier to be effective, its lateral width should extend beyond the line-of-sight at least as much as the height (See Fig.2.6). It may be noted that, the frequencies, represented on the X-axis of the graph in Fig., are the centre frequencies of the octave band. The barrier may be either close to the source or receiver, subject to the condition that, R <<D or in other words, to increase the traverse length for the sound wave. It should also be noted that, the presence of the barrier itself can reflect sound back towards

the source. At very large distances, the barrier becomes less effective because of the possibility of refractive atmospheric effects. Another method, based on the length of traverse path of the sound wave is given at Fig.2.7

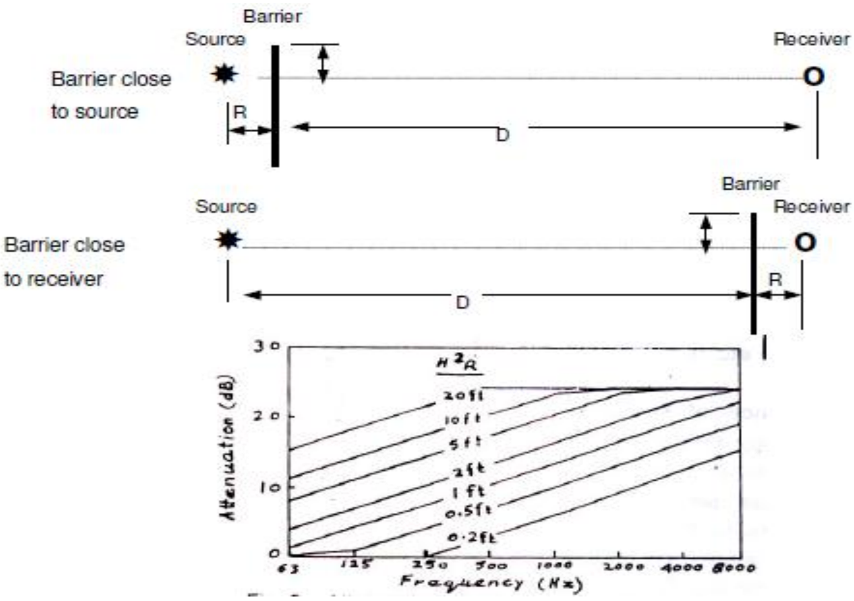

Fig2.6. Attenuation of noise barrier using barrier

(Source: discovery .bits-pilani.ac.in)

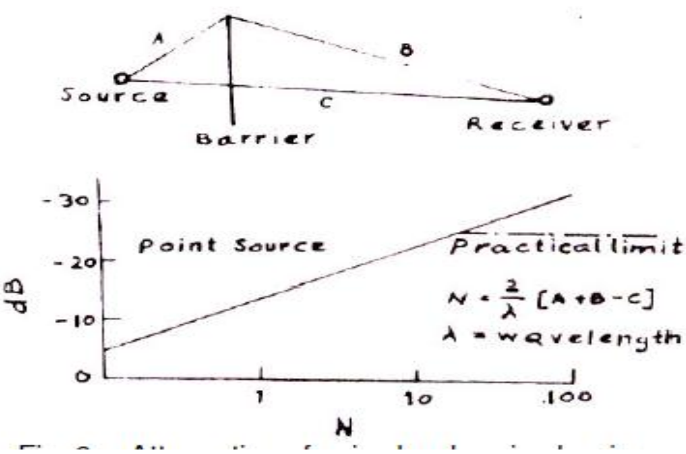

Fig.2.7. Attenuation of noise level using barrier

(Source: discovery .bits-pilani.ac.in)

Design of building

The design of the building incorporating the use of suitable noise absorbing material for wall/door/window/ceiling will reduce the noise levels. The reduction in noise levels for various frequencies and the A-weighted scale are shown. Variations in spectrum shape may change this A-weighted value by as much as +/- 3 dB.

A. Installation of panels or enclosures

A sound source may be enclosed within a panelled structure such as room as a means of reducing the noise levels at the receiver. The actual difference between the sound pressure levels inside and outside an enclosure depends not only on the transmission loss of the enclosure panels but also on the acoustic absorption within the enclosure and the details of the panel penetrations which may include windows or doors. The product of frequency of interest and surface weight of the absorbing material is the key parameter in noise reduction through transmission loss. With conventional construction practices, the high-frequency transmission loss of a panel becomes limited to around 40 dB, owing to the transmission of sound through flanking paths other than the panel itself. Examples of such flanking are structural connections or ducts joining the two spaces on either side of the panel of interest

B. Green belt development: Green belt development can attenuate the sound levels. The degree of attenuation varies with species of greenbelt. The statutory regulations direct the industry to develop greenbelt four times the built-up area for attenuation of various atmospheric pollutants, including noise.

2.2.6.1.3 Using protection equipment

Protective equipment usage is the ultimate step in noise control technology, i.e. after noise reduction at source and/or after the diversion or engineered control of transmission path of noise.

The first step in the technique of using protective equipment is to gauge the intensity of the problem, identification of the sufferer and his exposure to the noise levels. For the Regulatory standards pertaining to time of exposure vs. maximum noise levels permitted in a workspace environment, please refer to LO-8. The usage of protective equipment and the worker's exposure to the high noise levels can be minimised by -

- **Job rotation:** By rotating the job between the workers working at a particular noise source or isolating a person, the adverse impacts can be reduced.
- **Exposure reduction:** Regulations prescribe that, noise level of 90 dB (A) for more than 8 hr continuous exposure is prohibited. Persons who are working under such

conditions will be exposed to occupational health hazards. The schedule of the workers should be planned in such a way that, they should not be over exposed to the high noise levels.

- **Hearing protection:** Equipment like earmuffs, ear plugs etc. are the commonly used devices for hearing protection. Attenuation provided by ear-muffs vary widely in respect to their size, shape, seal material etc. Literature survey shows that, average noise attenuation up to 32 dB can be achieved using earmuffs.

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CHAPTER - 03

DUST AND NOISE SURVEY IN THE MINE: A CASE STUDY

3.0 DUST AND NOISE SURVEY IN BOLANI IRON ORE MINE: A CASE STUDY

3.1 INTRODUCTION

Bolani Ores Mines - SAIL is situated 10 Km west of Barbil in the Champua subdivision of Keonjhar district of Orissa, adjoining the boundary of Singhbhum (West) district of Jharkhand. The total lease area of Bolani mines is 12 sq. miles. The mine has been running since June 1957. Bolani Ores Mines is one of the major mechanized iron ore mine. There are 767 workers and 114 executives working in 21 different sections which cover from mining to school to hospital. The total mining lease hold area comprises of two Leases (5.10 Sq. Miles & 6.90 Sq. miles). The main iron ore mining area falls in 1st (5.10 Sq. Miles) lease whereas the colony, loading plant, old manganese quarries and the new tailing pond fall within the 2nd (6.90 Sq. Miles) lease.

Ore bearing area covers about 5 kms stretch on the eastern slope of famous BONAI IRON ORE RANGE. Within the lease there are nine ore bodies of various aerial extents having average depth of about 80 m, the width of the ore bodies varying from 180 m to 274 m. The mine-able reserves are of the order of 137 million tones and a further 134 Million Tonnes are likely under indicated reserve category.

Total geological reserves of iron ore in the Bolani Ore Mines is 259.09 Mt. Out of which, 137.72Mt falls under mineable reserve & 121.37 Mt under probable/indicated reserves category. 10 nos. of ore bearing areas, namely A, B, C, D, E, F, G, J, K and Panposh areas, were demarcated. Three ore bearing areas of Bolani Ore Mine viz. D, F & G areas are well explored. At present, mining operations are being carried out in F, G, D and Panposh areas. The process is conventional top slicing by shovel dumper combination. F and G areas are being mine departmentally and will continue to be mined in the same manner whereas Panposh and ‘D’ areas are being mined contractually and will continue in the same manner. In the expansion phase Bolani mine will operate 3-shifts/day for 300 days/year.

The planned production of Bolani is 4.49 MT of ROM, 1.39 MT of Lumps and 2.35 MT of Fines per annum. Major part of the iron ore production is met by mechanized mining in ‘F’ & ‘G’ Area. At present, Bolani is capable to meet the entire iron ore requirement of DSP and also additional requirement of other Steel plants on demand. Bolani has achieved ISO-14001 certification & ISO-9001 for CBRS.

Fig 3.1 Location of Bolani Iron Ore Mine

(Source: www. Wikimapia.com)

Figure 3.2 Map of the Bolan Iron Ore Mine

(Source: www.wikimapia.com)

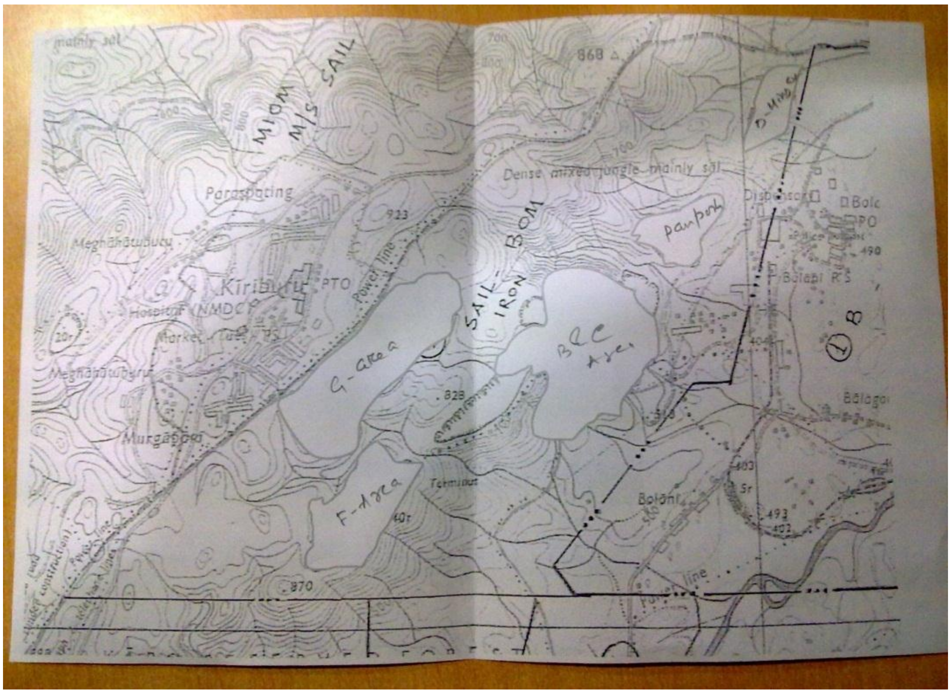


Figure 3.3 mine plan of the Bolani Iron Ore Mine

(Source: Bolani Iron Ore Mine)

Fig.3.4 Bolani Iron Ore Mines (F-area)

LIST OF MAJOR EQUIPMENTS

The details of the major heavy earth moving machineries of Bolani are as follows:

Table 3.1 LIST OF HEM EQUIPMENT

Type of Equipment	Make/Model	Capacity	HP/KW	Nos in Fleet.
ELECTRIC POWERED ROPE EXCAVATORS	HEC	4.6 Cu.M	250 Kw	1
DIESEL POWERED HYDRAULIC EXCAVATOR	BEML/BE1000	4.5 Cu.M	542 HP	3
	BEML / BE1600	7.5 Cu.M	808 HP (404+404)	1
	Komatsu/PC2000 -8	9.5 Cu.M	976 HP	1
DUMPERS	BEML 210M	50 T	635 HP	4
	Caterpillar 773D	50 T	635 HP	2
	BEML/BH50M	50 T	635 HP	2
	BEML /BH100	91 MT	983 FHP	2
	Komatsu HD785-7	91 MT	1200 HP	2
WATER SPRINKLERS	BEML/WS28-2	28KL	380 HP	2
DRILLS	IDM30	6.5”	400 HP	3
DOZERS	BEML/BD355	94,801 Kg Draw bar pull	416 HP	6
LOADERS	BEML/WA400	3.1 Cu.M	197 HP	1
	SEM/ZL60G	3.1 Cu.M	234 HP	1
	Kawasaki 90ZIV-2	3.1 Cu.M	197 HP	2
	Hyundai HL770-7A	3.7 Cu.M	280 HP	1
MOTOR GRADERS	BEML GD605R2	3700 mm	234 HP	1

	BEML BG825	4928 mm	280 HP	1
CRANES	Coles/Husky-640	40 T	180 HP	1
	Escorts	8 T	49 HP	2
	TIL / Husky - 620	20 T	152 PS	1
New Machines to be included in the Fleet				
TYRE HANDLER	BEML		PO Placed	

ORE PROCESSING PLANT

The following are the machineries that are being used in the ore processing plant.

Table 3.2 Ore processing plant machineries

Sl. No.	Equipment	Make	Capacity	Kilowatt	SIZE	No. of UNITS
1	PRIMARY (GYRATORY) CRUSHER	KOBE PVT LIMITED JAPAN	1600 T/Hr	370	1,350 mm DIA	1
2	SECONDARY (CONE) CRUSHER	NORDBERG UK	750 T/Hr	403	2,200 mm DIA	1
3	DRUM SCRUBBER WITH TROMMEL	NGEF	600 T/Hr	360	3 m X 9 m	2

3.2 DUST SURVEY

A personal dust survey in Iron Ore Mine Bolani was conducted during 26/03/2012 to 28/03/2012. The work was carried out at different places of the mine like loading area, crusher plant area, washing plant mine face and mine site office (hill top) and sampler was used by different types of operators/workers.

The experiment was done with the help of personal dust sampler APM 300 cwith a filter paper of diameter of 37 mm. The flow rate of the air to the sampler was kept at 2.2 l/min for 8 hours approximately for all the observations. For each observation the instrument was given to the worker or the operator with the filter paper pipe clipped to the collar to the worker for entire shift. After the completion of time the filter paper was taken out carefully and weighted in the balance. The dust concentration was calculated for all the samples by using the following formula. The dust concentrations of all the places have been given in the Table 3.3.

Dust concentration (mg/m^3) = $(W_1-W_0)*10^3 / (T*(R_1+R_2)/2)$

Where W_0 and W_1 are the initial and final filter weights in mg.

R_1 andR_2 are the flow rate in lpm at start and just before end of the run.

T is the total sampling time in minutes.

Fig 3.5 Bolani Iron Ore Mine- Ore processing plant

Fig 3.6 Bolani Iron Ore Mine- conveyor system

Table 3.3 Dust survey at Bolani Mine

Sl no.	Area of survey	Initial wt.(in g)	Final wt.(in g)	Dust concentration (limit 3 mg/m^3)
1	Worker at lump loading station	0.02736	0.02758	0.22
2	Worker at fine loading station	0.02725	0.02975	2.5
3	Operator at crusher plant area	0.02753	0.02865	3.1
4	Operator at washing plant	0.02698	0.02982	2.8
5	Operator at the mine face	0.02718	0.02842	1.2
6	Worker at mine site office	0.02713	0.02724	0.14

3.3 NOISE SURVEY

A field experiments were done at Iron Ore Mine Bolani for Noise during 26/03/2012 to 28/03/2012. The main sources for noises where the readings have been taken are loading station, hopper, gyratory crusher, secondary cone crusher, dumpers, shovel, drill machine, drum scrubber, double deck screen and de-watering screen. The sound levels were taken at different distances of the sources. It was measured at different distances from the different sources varying from 1 to 10 m from the sources.

Instrumentation

The instrument used for the measurement was The B&K Sound Level Meter. It has display the A-weighted sound pressure level on a 40 dB column display and have a total measurement ranging from 25 to 150 dB(A). Also an additional “F” and “S” time constant.it has basically four measurement modes

L_{eq} (L_{Aeq}), A-weighted SEL (L_{AE}), Max. Hold “F” or “S” and Max. Hold “Peak”. The first three are A-weighted whereas fourth is measured with a flat frequency response. It has four overlapping sensitivity ranges provide a measurement span from 25 dB to 145 dB for L_{eq} measurement. It also provides data in L_1 L_{10} and $L_{90.}$

The readings of different areas at different distances ware taken. The data of the survey have been given in the Table 3.4.

Fig 3.7 Bolani Iron Ore Mine- mine face

Fig 3.8 Bolani Iron Ore Mine- Working face

Table 3.4

Measurement of noise from different noise sources in the Bolani Iron Mine

NOISE SOURCE	F	L_{eq}	SEL	LEpd	L_1	L_{10}	L_{90}	MAX_L	MIN_L	MAX_P	DURATION
LOADING STATION @ 01m	F	88.1	107.4	87.8	92	89.5	85	96.9	84.1	113.8	1:24
@ 05m	F	87.2	104.5	86.9	91.5	89	83.5	92.6	72.6	109	0:53
@ 10m	F	86.6	102.8	85.7	90.8	88.6	82.2	86.9	70.3	104.3	1:03
HOPPPER @ 10m	F	82.8	102.1	82.7	87.5	85	78.5	94.8	75.4	100.5	1:20
GYRATORY CRUSHER	F	89.5	109.4	91.2	95.2	91.6	86.6	103.2	84.3	109.1	0:56
SECONDARY CONE CRUSHER	F	102.2	117.4	101.6	107.5	104	96.8	119	93.1	123.2	1:34
DUMPER (55 T) INSIDE CABIN	F	93.2	112.6	94.4	99	96.5	91.5	102.2	89.6	112.6	1:03
" " " WITH DOOR CLOSED	F	91.6	111.7	91.4	97	94.5	87.5	91.7	91.5	110.4	1:07
SHOVEL PC200 @ 2m	F	87.5	104.2	86.5	91.2	88.5	84	92	75.2	108.5	1:04
" " " INSIDE THE CABIN	F	80.1	98.8	78.6	83.1	82.4	77.5	97.4	78.4	97.8	1:08
" " " WITH DOOR CLOSED	F	78.2	97.5	78.2	82	80.5	76	79.8	78.1	95.3	1:18
DRILL MACHINE @ 2m	F	92.1	111.5	91.8	98.5	95	88.1	99.5	85.4	110.4	1:25
" " " INSIDE THE CABIN	F	95.3	115.1	94.9	100	97.5	91	95.8	95.1	114.4	1:28
" " " WITH DOOR CLOSED	F	91.4	111.2	91	96.4	94.2	89.8	91.3	91.5	112	1:24
DRUM SCUBBER	F	96.5	117.5	95.8	102.5	98	93	102.3	83	116.8	1:30
DOUBLE DECK SCREEN	F	96.2	116.5	95.5	101.8	99.5	92.5	108.1	88.5	116	1:32
CONTRL ROOM	F	76.2	90.1	76	72.5	77.8	73.8	83.6	75.8	95.8	1:22
DE-WATERISER SCREEN	F	96.2	117.8	96.5	92.5	97.8	92.1	106.3	92.7	117.8	1:09

3.4 RESULT AND DISCUSSION

A. DUST SURVEY

The results of dust survey of the Iron Ore Mine Bolani are given in the Table 3.3. From the table it is clear that the dust level at the mine site office was minimum (0.14 mg/m^3) whereas the maximum dust level was found at the crusher plant area (3.1 mg/m^3). The dust concentration at lump loading station, fine loading station, mine face and mine site office was less than safe working limit(3 mg/m^3) whereas at the washing plant and crusher plant area were found more than the safe working limit. Therefore the workers should be provided with personal protective equipment especially who are going to the crusher plant area.

B. NOISE SURVEY

The result of noise survey of the mine is given in the Table 3.4. The maximum noise level was found to be from secondary cone crusher 102.2 dBA. It was mainly due to crushing of the materials producing high noise level. Whereas the minimum noise level was found from the control room 76.2 dBA. The noise level at dumper, drill machine, drum scrubber, double deck screen and dewatering screen was more than 90 dBA which is maximum permissible limit for 8 hrs working period. Whereas the noise level at loading station, hopper, shovel, and control room was below the permissible limit 90 dBA. There was no worker working with any protective equipment which could lead to hazardous effect on the worker. It can be of temporary or permanent hearing loss. Therefore the workers either should be provided with ear plug or ear muff before going to the field or minimize the exposure time to the field.

Hence we can say that the worker of the Iron Ore Mine, Bolani are working under high noise level more than the acceptable level.

3.5 CONTROL MEASURES

3.5.1 Dust Control Measures at Bolani Iron Ore Mine

Dust suppression is achieved by the following two methods:

A) Dust Suppression System (DS System) - Wet

B) Dust Extraction System (DE System) - Dry

Fig 3.8 Water spraying system

A) Plain water is used for settling the dust. A chemical compound is dosed in the water before spraying by water sprinklers. The water thus used spreads in the form of a thin film on the dust surface instead of collecting in the form of droplets giving rise to rapid and thorough wetting of the dust particles resulting in reduction of dust in the air.

The Ore processing plant is equipped with 4 packages of the dust suppression system in the following areas:

The feed water is pumped by the feed water pump and is dosed with the chemical compound in a ratio of 1: 4000 and this solution is mixed in the solution tank of the mixing chamber. The solution is pumped by the solution pump and is sprayed through the spray headers.

Package A	Crushing Plant Main Building
Package B	PSP Area
Package C	Washing Plant Area
Package D	Fines Loading Area

Each package of the DS System consists of the following equipment:

Feed Water tank

Mixing Chamber

Feed water Pump

Metering Pump

Solution Pump

Under-belt control Switch

Solenoid Box

Spray header with nozzles

Chemical compound (COALSETX - P)

B) Dust extraction System is designed to capture the dust right from their generation point by different suction hoods and paving way to Bag filter unit. Dust gets separated from the air when it passes through the bag filter and hence clean air is discharged into the environment through a chimney. The dust particles deposited on the bag filters are cleaned by the compressed air jet pulse from the reverse direction and the dust is allowed to settle at the bottom of the hopper, from where it is discharged on another conveyor with the help of rotary air lock motor.

- The dust extraction system installed at OPP consists of the following:

  Suction Hoods

  Ducting

  ID Fan

  Exhaust Chimney

  Rotary air lock Valve

  Bag Filter Unit

  Compressor

  Air Dryer/Moisture & oil eliminator

  Air Pressure regulator cum filter

Suggestions for the control measures for dust production

As we have seen that the mine is using wet and dry depression techniques for the suppression of the dust, but they are not working for the dust generation i:e they can go for the new machines or keeping the machine well maintained. Also they are not using any personal protective equipment which can also be implemented for the dust control. The exposure time can also be reduced as to avoid serious effect of the dust.

3.5.2 Noise Control Measures at Bolani Iron Ore Mine

For controlling the noise in the mines, there is no particular measure has been taken. But the workers are found to be working in the field without any precautions.

Suggestions for the control measures for Noise Production

They can go for different techniques for controlling the production of noise in the mine.

- They can go for the mechanisation of the mine i:e machine should be kept in well maintained condition.
- They can provide personal protective equipment for the worker going for the work.
- The exposure time of the workers can also be reduced

3.6 INFERENCES

- The results of dust survey of the Iron Ore Mine Bolani are given in the Table 3.3. From the table it can be clearly observed that the dust level at the mine site office was minimum (0.14 mg/m^3) whereas the maximum dust level was found at the crusher plant area (3.1 mg/m^3). The dust concentration at lump loading station, fine loading station, mine face, washing plant and mine site office was less than maximum permissible limit whereas at the crusher plant area was found more than the maximum permissible working limit.

- The results of noise survey are given in the Table 3.4. From the table it is clear that the noise level at the secondary cone crusher is maximum (102.2 dBA) whereas at the control room minimum (76.2 dBA). The noise level at dumper, drill machine, drum scrubber, double deck screen and dewatering screen was more than 90 dBA which is maximum permissible limit for 8 hrs working period. Whereas the noise level at loading station, hopper, shovel, and control room was below 90 dBA. Hence we can say that the worker of the Bolani Iron Ore Mine, are working under high noise level more than the acceptable level.

CHAPTER- 04

FUZZY MAMDANI SYSTEM FOR EVALUATING NOISE RATING (NR)

4.1 INTRODUCTION

This proposed model was designed with MATLAB Fuzzy logic Toolbox. Initially the inputs were classified into its linguistic variables and Fuzzified by triangular membership function. As this proposed model is a Mamdani Fuzzy Model (1975), hence the output of the system should be fuzzified as similar to the inputs of the system. After successfully classification of the membership system to the both input and output using Fuzzy logic Toolbox, Rule Editor, all the rules were selected. Foe this system, the first input has 3 memberships function while second has 5, third has 5 and fourth has 5.so total 3*5*5*5= 375 rules selected. After defuzzification with the rule viewer, the output has been represented in crisp value.

This proposed system has aim to find the noise rating (NR). The detail of the whole work has been given below.

A fuzzy system includes nonlinear mapping of an input data vector in to a scalar output using fuzzy logic. It is performed using the fuzzification, fuzzy inference, and defuzzification. The objective of fuzzifier is to determine the degree of membership of a crisp input in a fuzzy set. The fuzzy rule-base is used to represent the fuzzy relationship between input-output fuzzy variables. The output of the fuzzy rule-base is determined based on the degree membership specified by the fuzzifier. The inference engine calculates the rule's conclusion based on its membership degree. Optionally, if needed, a defuzzifier is used to convert outputs of the fuzzy rule-base in to crisp values. Figure 4.1, illustrates a block diagram of a typical fuzzy system.

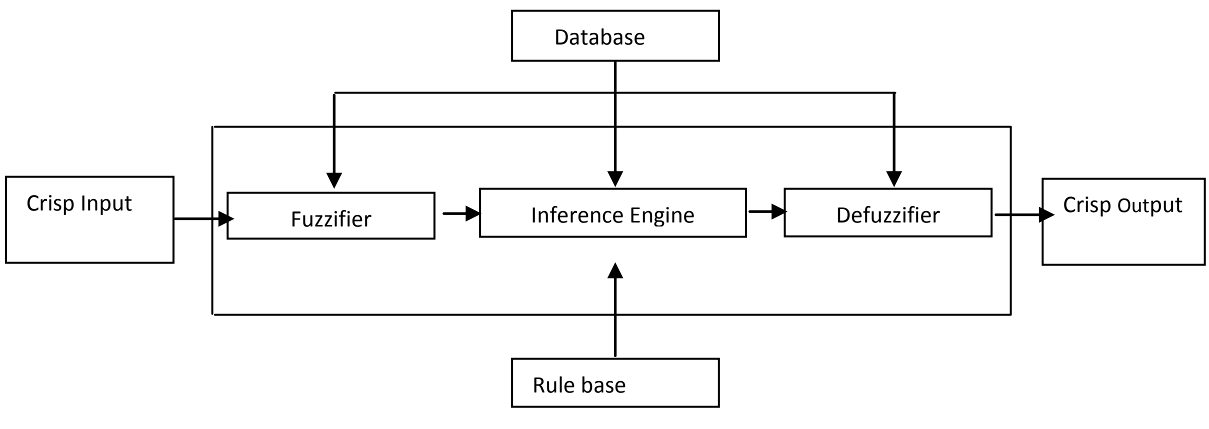


Figure 4.1 Block diagram of fuzzy system

Source: Ross, Timothy J., Fuzzy Logic With Engineering Applications, McGraw-Hill International Edition, New York, 1997, 17-212

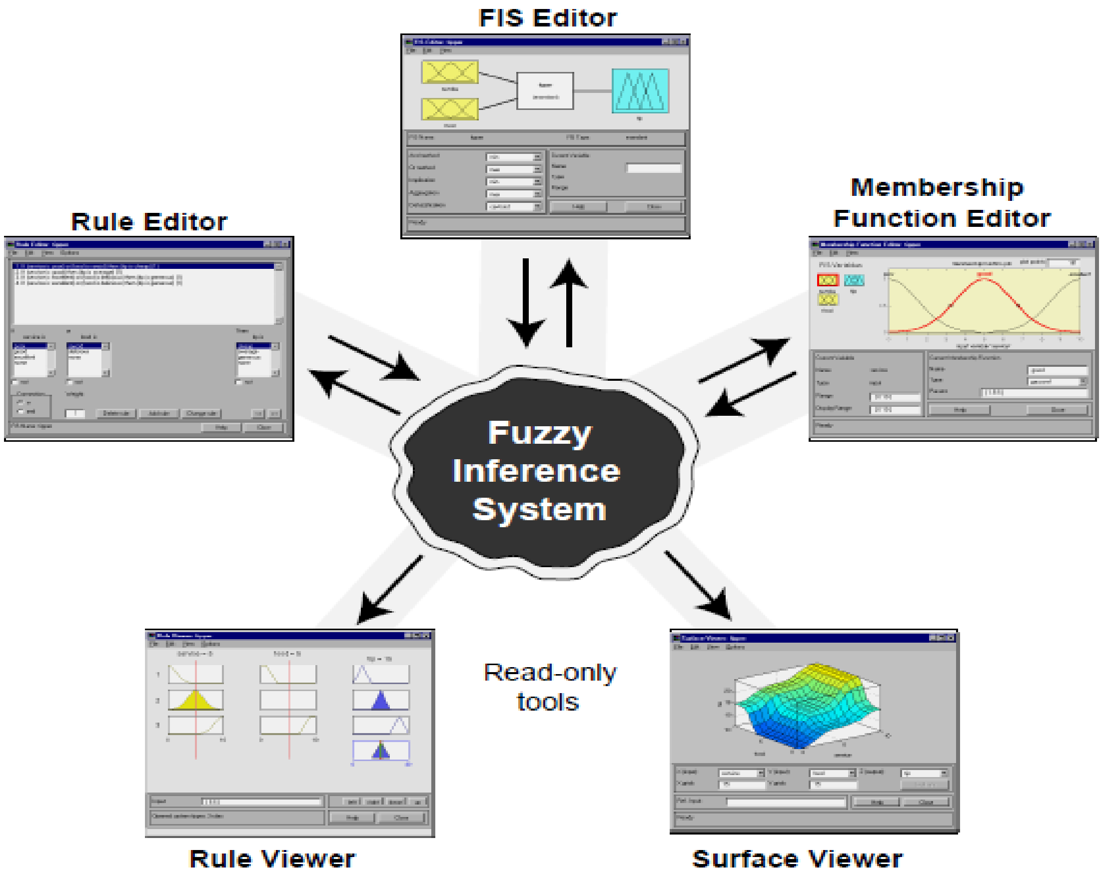


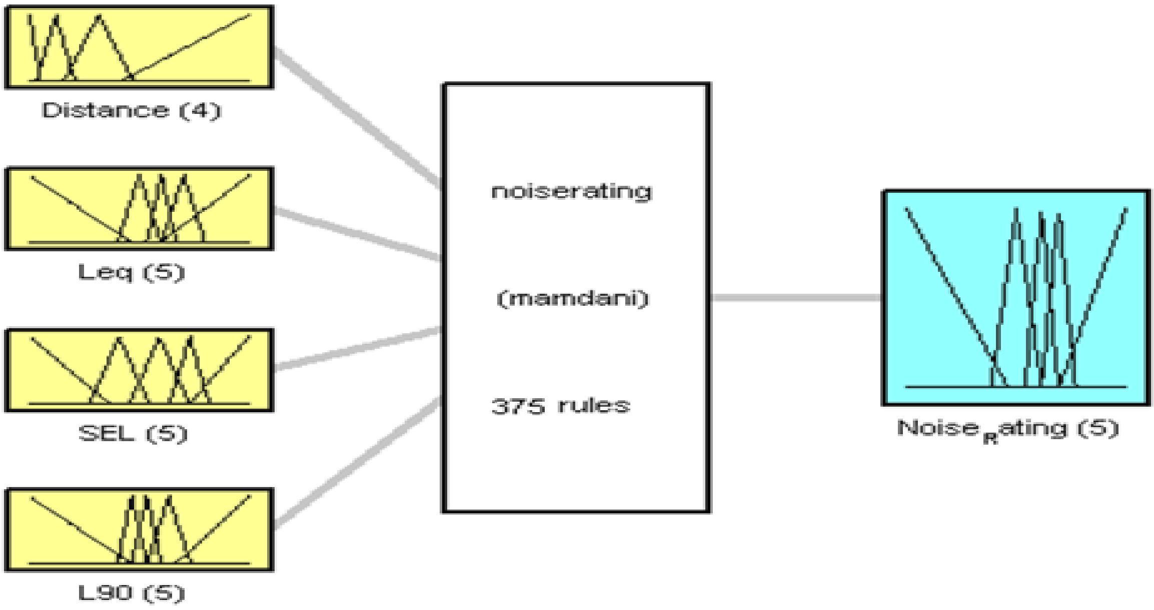
Figure 4.2 Fuzzy inference systems

4.2 METHODOLOGY

Noise rating(Y) as a function of distance (X_1) L_{eq} (X_2), SEL (X_3) and L_{90} (X_4) can be mathematically expressed as given by equation:

$$Y=f\ (X_1, X_2, X_3, X_4)$$

Step 1: Identification of input and output variables: The present fuzzy system has four input variables: L_{eq}, SEL, L_{90} and distance from the source. The output variable is the Noise rating(NR). Figure4. 3, represents Block diagram of Mamdani's MISO (Multi input single output) model.



4.3 Block diagram of Mamdani's MISO (Multi input single output) model.

Step 2: Selection of input and output variables: The inputs and outputs with their linguistic values and fuzzy intervals are shown in Table 4.1.

TABLE 4.1 Inputs and outputs with their linguistic values and fuzzy intervals

SL.no/Level	System linguistic variable	Variables	Linguistic Value	Fuzzy interval
1	Inputs	Leq (Equivalent Noise Level)	Low Medium High Very high Extreme	40-75 dBA 70-85 dBA 80-90 dBA 85-100 dBA 85- 115 dBA
2.	Inputs (Change)	SEL (Sound Emission Level)	Low Medium High Very high Extreme	70-90 dBA 85- 100 dBA 95-110 dBA 105-115 dBA 110-125 dBA
3.	Inputs	L90 (Equivalent Noise Level with 90 % level)	Low Medium High Very high Extreme	40-75 dBA 70- 80 dBA 75-85 dBA 80-95 dBA 90-115 dBA
4.	Inputs	Distance (Influence)	Low Medium High Very High	5-10m 8- 25m 20-50m 45-100m
5.	Output	NR (Noise Rating) in dB(A)	Low Medium High Very high Extreme	50-80 dBA 75- 90 dBA 85- 95 dBA 90-100 dBA 95-115 dBA

Step 3: Determining the linguistic labels and membership function for various input and output variables: The inputs variables has been decomposed in to the following set of terms i.e. noise rating ={low, medium, high, very high, extreme},L_{eq}={ low, medium, high, very high, extreme} SEL ={ low, medium, high, very high, extreme }, L_{90}= { low, medium, high, very high, extreme } and distance { low, medium, high, very high}. The triangular functions were selected due to their simple formula and computational efficiency.

Step 4: Formation of the set of IF-THEN rules: The relationship between input and output are represented in the form of IF-THEN rules. As per given inputs and output, a maximum of 375 rules were generated. For example;

IF Distance is Low and L_{eq} is very high and SEL is medium and L_{90} is very high **THEN** NR (noise rating) is high.

Defuzzification

In this proposed model, Centroid of area method of defuzzification is used for determining the output

$$\frac{\int_Z \mu A(z) z dz}{\int_Z \mu A(z) dz}$$

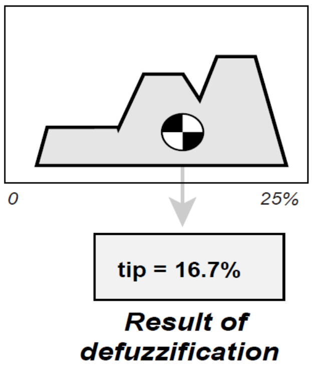


Fig. 4.4 Defuzzification output

The membership functions of different parameters are given below;

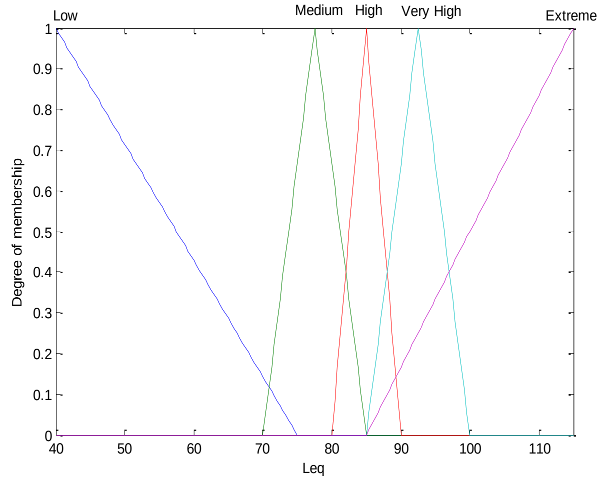


Figure 4.5 Membership function of L_{eq}

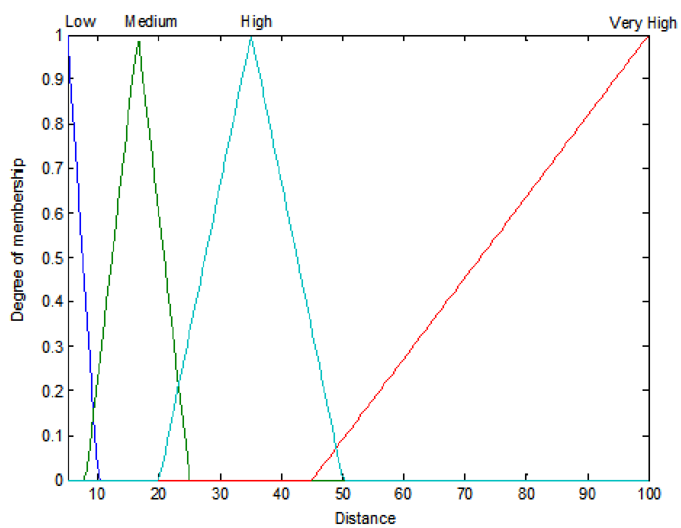


Figure 4.6 Membership function of Distance

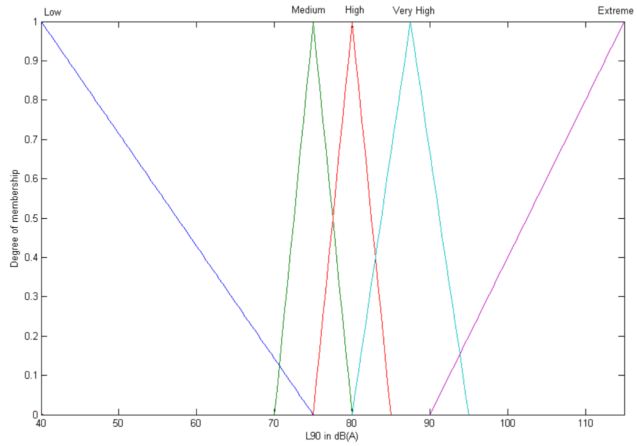


Figure 4.7 Membership function of L_{90}

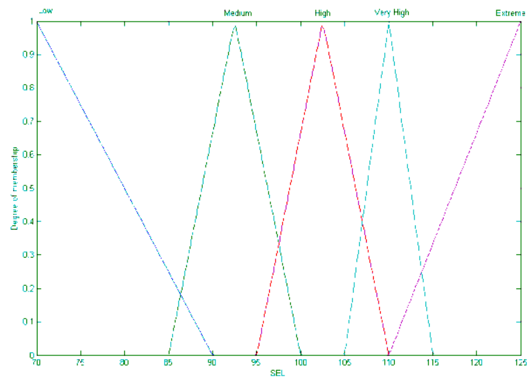


Figure 4.8 Membership function of SEL

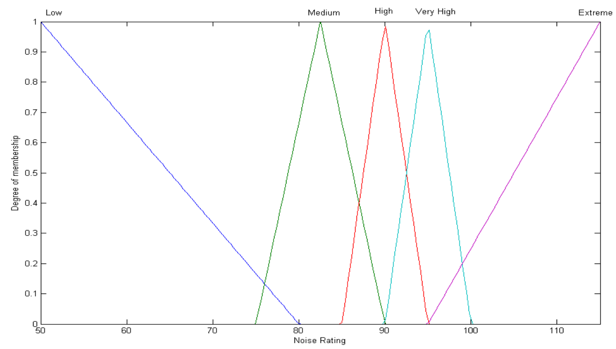


Figure 4.9 Membership function of Noise Rating

Figure 4.10 Rule Viewer of Fuzzy Model

4.3 RESULTS AND DISCUSSION

After putting the input values for all the variables and for the output, the noise rating was found out which was compared with the calculated noise rating of the field data. Following is the table for the comparison of the field survey data to the model data that is the noise rating of the field survey and of the model and it was found to be very close to the field survey value.

TABLE 4.2 Comparison between field and model NR

Machinery	Distance(in m)	L_{eq}	SEL	L_{90}	Field NR	Model NR
Loading station	8	88.1	107.4	89.5	**93.1**	**92.7**
Gyratory crusher	9	89.5	109.4	86.6	**94.7**	**93.7**
Hopper	8	82.8	102.1	78.5	**87.3**	**82.5**
Secondary cone crusher	7	102.2	117.4	96.8	**107.4**	**106**
Dumper	6	93.2	112.6	91.5	**98.4**	**100**
Shovel	6	80.1	98.8	77.5	**85.3**	**82.5**
Drill machine	6	92.1	111.5	88.1	**97.4**	**98.2**
Drum scrubber	6	96.5	117.5	93	**101.5**	**106**

4.4 INFERENCES

From the modelling of the Noise rating from Mamdani Fuzzy System, the noise rating for different machineries were determined and compared with the field data for the Noise Rating and it was found that the results were satisfactory.

CHAPTER 05

CONCLUSION

CHAPTER 5

CONCLUSIONS

From dust and noise survey carried out in Bolani iron ore mines, it was observed that:

- The dust level at the mine site office was minimum (0.14 mg/m^3) whereas the maximum dust level was found at the crusher plant area (3.1 mg/m^3). The dust concentration at lump loading station, fine loading station, mine face and mine site office was less than safe working limit(3 mg/m^3) whereas at the washing plant and crusher plant area were found more than the safe working limit.
- The noise level at the secondary cone crusher was maximum (102.2 dBA) whereas at the control room minimum (76.2 dBA). The noise level at dumper, drill machine, drum scrubber, double deck screen and dewatering screen was more than 90 dBA which is maximum permissible limit for 8 hrs working period. Whereas the noise level at loading station, hopper, shovel, and control room was below the permissible limit 90 dBA. Hence we can say that the worker of the Iron Ore Mine, Bolani are working under high noise level more than the acceptable level.
- From the modelling of the Noise rating from Mamdani Fuzzy System, the noise rating for different machineries were determined and compared with the field data for the Noise Rating and it was found that the results were satisfactory.

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